Elk Hills Power

January 27, 2012

Mr. David Albright
Manager, Ground Water Office
United States Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, CA 94105-3901

Dear Mr. Albright:

Elk Hills Power (EHP) is submitting the attached response to your letter dated December 14, 2011 in which the United States Environmental Protection Agency, Region IX (EPA), as part of its continuing technical review, requested additional information and clarifications of previously submitted information. The information with this letter is provided as a supplement to the Elk Hills Power UIC Permit Application for Class I Non-Hazardous Injection Wells.

The original EHP Permit Application was submitted to EPA on September 15, 2010 within 180 days prior to the permit expiration on February 21, 2011. The Permit Application was updated on July 27, 2011 in response to the Technical Review letter dated March 2, 2011 from Mr. George Robin of EPA.

The attachments to this letter include an item-by-item list of responses to the EPA's questions and comments in its December 14, 2011 letter and two (2) sets of hard copies of inserts to be replaced in the July 2011 application document. Finally, there is a fully updated electronic copy of the Permit Application containing all revisions.

Please feel free to contact Mr. Ricardo Medina at (661) 763-2727 or Mr. Sonnie Pineda at 763-2725 if you have any questions or further requests.

Very truly yours,

Ricardo Medina
Elk Hills Power

Enclosures

EPA Request for Information
Underground Injection Control (UIC) Permit Application
Class I Non-Hazardous Wells
Elk Hills Power – R9UIC-CA1-FY10-2R

Response to Elk Hills Permit Application Questions and Comments (12-14-2011)

1. The calculations of the Area of Review (AOR) waste front (with and without dispersion) and the pressure front calculation for past and projected future cumulative injection through 2022 appear to be correct. Calculations were checked for both the "current rate forecast" and "high rate forecast". However, there is little discussion of the basis for the calculations. Please provide a brief discussion of the methodology and assumptions used to develop the current rate forecast and high rate forecast. EPA will use the high rate forecast for its evaluation of the Permit Application.

   In addition, please provide a background discussion of the methodology used to select input parameters for the AOR calculations. Several input parameters were determined based upon samples from well 46WD-7G. Please explain why this well was selected, and include justification of why the samples are considered representative of the injection well formation. Additionally, please explain the basis for estimating the compressibility of the injection interval. Page 19 of the application states that compressibility of the injection interval was estimated based on compressibility values for consolidated sandstones with porosity of 26 percent at a lithostatic pressure of 0.75 psi/ft. However, the porosity of the injection interval was determined to be 34 percent, based upon samples from well 46WD-7G. Please explain this difference and why 26 percent porosity was used for the estimate.

   Response: The Area of Review for this application was evaluated using the volumetric method of Warner and Lehr (EPA document 600/2-77-240, December 1977). This method is a standard, industry accepted method which compares the injection volumes with the porosity and storativity of the injection zone. The methodology assumes that the injected wastewater will uniformly occupy an expanding cylinder away from the injection wells assuming horizontal flow and estimates of the influence of dispersion.

   *There are many simplifying assumptions to the Warner and Lehr methodology that limit its ability to predict wastewater travel; however, no other attempts have been made to determine the actual wastewater distribution around the permitting wells, so there is no evidence for comparison with theory. As a result, the Warner and Lehr formulas are relied on for a first order approximation of the location of the waste front. The calculations in **EXHIBIT A-4** show an area of influence of 891 feet and 1,067 feet after a total of 20 years of injection for the current rate and maximum rate forecasts, respectively. These distances are sufficiently less than the AOR of 2,650 feet to allow for the limitations of the methodology and any additional complications.*

The waste front calculations are presented for both a current rate and high rate case after taking into account the actual wastewater injection volumes through the year 2010. The current rate forecast is determined using a two-year average of the disposal rates for the most recent operational history, years 2009 and 2010. The high rate forecast case is based on the design capacity of the power plant and it represents the maximum possible daily wastewater volume.

Well 46WD-7G was selected to determine several of the input reservoir parameters because 1) the well was cored in the target Tulare zone and 2) the Tulare zone in the well is stratigraphically equivalent and on the same structure as the permitting wells (even though it is outside of the AOR). In addition, the observed core porosity and permeability data from well 46WD-7G were in good agreement with published porosity and permeability information from the California Division of Oil, Gas and Geothermal Resources (DOGGR) for the Tulare zone at the neighboring Elk Hills oil field. Finally, the range of core permeabilities in the 46WD-7G are consistent with the average permeabilities calculated from the historical falloff tests in the permitting wells.

In the Permit Application, the reservoir compressibility value for the Tulare injection interval was estimated using Hall's Correlation for consolidated sandstones even though the Tulare zone is more properly characterized as unconsolidated sandstone due to its shallow depth and high permeability. If we were to consider pore volume compressibility data for unconsolidated sandstones as evaluated by Newman, 1973 (see figure below), we would find that there is no correlation comparable to Hall and if there is a correlation for unconsolidated samples, the trend may be opposite the trend for consolidated samples.

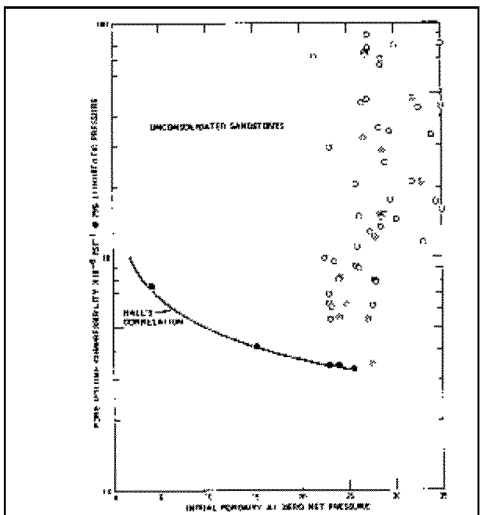


Fig. 6—Pore-volume compressibility at 75 percent lithostatic pressure vs initial sample porosity for unconsolidated sandstones.

FEBRUARY, 1973

Unfortunately, for unconsolidated reservoirs, formation compressibility should be measured for the reservoir being studied. At best, correlations can be expected to give only order-of-magnitude estimates. This is the reason that the value of 3.4 x 10-6 psi-1 was selected for this application. It was the lowest value of compressibility in the Newman cross-plot for the Hall's Correlation. The pore volume compressibility values for unconsolidated samples with porosities in the range of 30 – 35 percent were all significantly higher and scattered.

In the Permit Application, reservoir compressibility is used for the Pressure Front Calculations to predict the pressure at any distance from the injection well. In these calculations, the predicted pressure distribution away from the injection well decreases with increasing reservoir compressibility. For example, if a compressibility value of 30 x 10-6 psi-1 is used in the calculations in ***EXHIBIT A-5*** *(an order of magnitude higher than the value used in the application), the maximum pressure drop decreases by 3 psi. For this reason, to error on the side of a higher pressure drop, the value of 3.4 x 10-6 psi-1 was assumed for the Tulare reservoir compressibility.* ***EXHIBIT A-5*** *is revised to evaluate the pressure front for a higher reservoir compressibility of 30 x 10-6 psi-1.*

2. Map symbols for Exhibit B-3 are very hard to read. Please provide a better map with more color variety and greater shape difference between symbol types to allow better identification of well types. It is not clear why some symbols are red and some are black. Please revise the legend to explain the reason for the two colors.

   Response: ***EXHIBIT B-3*** *is revised to be more legible and in a larger size. The revised exhibit provides the requested color and shape variety changes to allow for better identification of well types.*

3. The geological cross sections (F-8 and F-9) were not updated since the original permit application. In EPA's March 2, 2011 Technical Review Letter (EPA letter), we specifically requested that the geological cross sections be re-drawn to include data obtained from the permitted wells (25-18G, 25A-18G, 35-18G and 35A-18G) constructed under the existing permit. The submitted geological cross sections do not include the permitted wells and data obtained from them. Also, all wells included in the cross sections should be legibly labeled with the well identification on both the cross sectional amps (Exhibit f-8) and the topographical map of the two cross sections (Exhibit F-7). Data from all four injection wells could be included in Cross Section A - A', since this cross section follows a similar west to east direction as the line of wells 25-18G, 25A-18G, 35-18G and 35A-18G. Please redraw A - A' to include these wells or explain why they are not included. Cross Section B - B' is oriented in an approximate north to south direction. Because of its perpendicular orientation to A - A', it may be difficult to include data from all four injection wells. Please redraw B - B' to include as many of the four injection wells as possible or provide explanation as to why they are not included.

*Response: Geological cross sections A-A' and B-B' are re-drawn to include data obtained from the permitted wells. Cross section A-A' (**EXHIBIT F-8**) includes data collected from permitted wells 25-18G and 35-18G. Wireline logs were not run in permitted wells 25A-18G and 35A-18G during their construction and therefore are not available for incorporation into Cross Section A-A'.*

*Updated cross section B-B' (**EXHIBIT F-9**) incorporates data collected from permitted well 35-18G. Due to the north-south orientation of cross section B-B' and the east-west alignment of the permitted wells, well 25-18G was not projected onto Cross Section B-B'. As discussed above, logs were not run in permitted wells 25A-18G and 35A-18G during their construction and there are no data available for Cross Section B-B'.*

*The topographical map, **EXHIBIT F-7**, is revised to legibly label the path and well identification of the two cross-sections.*

4. Portions of the paper copy of the application are poorly labeled and indexed. For example the Attachments section to Exhibit A-1 containing many plastic sleeves with large, folded drawings, is not indexed. This makes finding a specific map very difficult. Please provide labeled tabs for the plastic sleeves so that navigation among the large drawings may be improved.

*Response: The plastic sleeves in **EXHIBIT A-1** have been labeled for easy indexing of the maps and exhibits contained in each sleeve. The labeling of the contents of each sleeve is also improved to aid navigation among the drawings.*

5. Attachment I "Formation Testing Program" appears to have errors. For example, page 27 states "A summary of the static formation pressure since 2003 is presented in the table below." However the table only contains data from a test in 1999 and 2005. The table does not contain annual data from 2005 through 2010. Please include all available data from 1999 through 2010 or explain why it is not included.

Response: A fresh copy of the page 27 table is reprinted for the Permit Application. All available annual static formation pressure data from 2005 through 2010 should be visible in the summary table. An additional data point is included for the static pressure measured in July 2003 for well 35-18G.

6. Discussion of the fall off test results mentions a high skin factor during recent tests. The cause is not identified, but the discussion says: "These wells tend to fill up with sand and silt particles over time and the wellbores occasionally need to be cleaned out back to their total depth." Please include a proposed plan and schedule to do this as part of regular well maintenance.

*Response: The annual Pressure Fall-off and Mechanical Integrity Test procedure (**EXHIBIT I-1**, page 1) includes a plan to verify that the slotted liner completions in the*

*permitting UIC wells are not plugged by fill material. Prior to commencing the test procedure, the fill level is determined by running in hole with sinker bars on slickline and tagging bottom. The well/s will be cleaned out as needed. All permitting wells will be tested in this manner at the time of the annual falloff test. For time periods between the annual fall-off tests, the UIC wells are monitored through Hall Plots and continuous wellhead pressure readings (see **ATTACHMENT H**, Operating Data and **EXHIBIT H-5**). If there is an indication of plugging in a well as evidenced by an increasing wellhead pressure, the procedure for tagging bottom and cleaning out fill material will be followed at that time as described in the annual falloff test procedure.*

7. The Step Rate Test (SRT) data in EPA's project files are on a floppy disk. Unfortunately, some of the files are unreadable and appear to be corrupted. Please provide EPA with an electronic copy of the complete SRT data and include a conversion from spinner rate to flow rate.

   If possible, the SRT data should be submitted in the example format provided below:

DATE	TIME	INJ. PRESS (PSIG)	INJ. RATE (GPM)
11/27/11	16:33:16	1525.6	65.8
11/27/11	17:33:16	1525.4	66.3

   Each data line shall include four (4) values separated by a consistent combination of spaces or tabs. The first value contains the date measurement in the format of mm/dd/yy or mm/dd/yyyy, where mm is the number of the month, dd is the number of the day and yy or yyyy is the number of the year. The second value is the time measurement, in the format of hh:mm:ss, where hh is the hour, mm are the minutes and ss are the seconds. Hours should be calculated on a 24-hour basis, i.e. 6 PM is entered as 18:00:00. Seconds are optional. The third value is the well head injection pressure in psi. The fourth column is injection rate in gallons per minute.

   Additionally, please provide a summary and analysis of the surface injection pressures for each well over the prior years of operation since injection began. The discussion should include maximum and average surface injection pressures for each well and data analysis, with a discussion of any surface pressure trends over the entire operational history. Please provide more analysis to support the statement in the current version of the Permit Application on page 29 that: "...the permitted injections wells are capable of operating at surface wellhead injection pressures well below the 80 percent limit of 177 psig•"

   Response: A step rate test (SRT) to estimate the formation parting pressure (FPP) was conducted for injection well 35-18G on July 18, 2003. Surface and bottomhole injection pressures were recorded for a series of increasing injection rates (10 rates). The results

*and analysis of the SRT are presented by **EXHIBIT I-2**. As requested, an electronic copy of the SRT data is included on a **CD-ROM** with this response and with the Permit Application.*

***EXHIBIT I-2** is a graph of the bottomhole injection pressure at the end of each rate plotted versus the injection rate. There is no break in a line segment through the data points which indicates that the FPP was not reached during the test. The test ended at a maximum injection rate of 384 gallons per minute and a surface pressure of 248 psi (521 psi bottomhole pressure). The conclusion from this SRT is that the surface injection pressure will have to be greater than 248 psi before the injection will fracture the formation. The 80 percent limit for a 248 psi surface pressure level is 198 psi.*

*The surface injection pressure data for the permitting wells over the prior years since injection began are provided in **EXHIBIT H-5**. A graphical presentation of the surface wellhead pressures and rates versus time is given by **EXHIBIT H-3**. The maximum and average surface pressure trends over the last six months of 2010 are shown in the tables on page 23 of the Permit Application **ATTACHMENT H**, Operating Data. Since 2004 wastewater from the plant has been disposed of principally in two wells, 25A-18G and 35A-18G. The following conclusions are made based on the data in **EXHIBIT H-5** for the permitting wells:*

> *Well 25A – 18G: The average surface pressure of all of the injection-days through March 31, 2011 is 11.2 psig. During its operational history starting in January 2004, there are only a handful of surface pressures readings greater than 125 psig. These high pressures are not sustainable and subsequent pressure readings return to zero or less than 75 psi. There is no trend in the surface pressure data over the operational history; however, the average surface pressure of the injection-days in 2010 increased to 20.6 psig.*
>
> *Well 35A – 18G: The average surface pressure of all of the injection-days through March 31, 2011 is 6.6 psig. During its operational history starting in January 2004, there are only a handful of surface pressures readings greater than 125 psig. These high pressures are not sustainable and subsequent pressure readings return to zero or less than 75 psi. There is no trend in the surface pressure data over the operational history; however, the average surface pressure of the injection-days in 2010 increased to 47.2 psig.*
>
> *Well 35 – 18G: The average surface pressure of the injection-days through March 31, 2011 is 89.5 psig. This well has a history of high surface injection pressures (150-190 psig) especially during 2003 when it was on full time injection. Since the construction of wells 25A-18G and 35A-18G in January 2004, well 35-18G has been retired from general use as an injection well.*

8. Water samples were not collected from any of the four injection wells constructed by EHP; however, a Tulare water sample was collected in December 2008 from a well approximately two miles away in Section 14B. Please justify why the sample from the well in Section 14B is representative of the formation water in the vicinity of the injection wells.

Response: The Tulare Zone water sample collected and analyzed in December 2008 from water source well 2282WS-14B is considered a representative sample of the original formation water in the vicinity of the permitting wells for the following reasons:

a) *Well 2282WS-14B is approximately 1.5 miles west-northwest from the permitted well site which is outside of the calculated waste front and far enough away to be free of any endangering influence from the historical water injection volumes;*

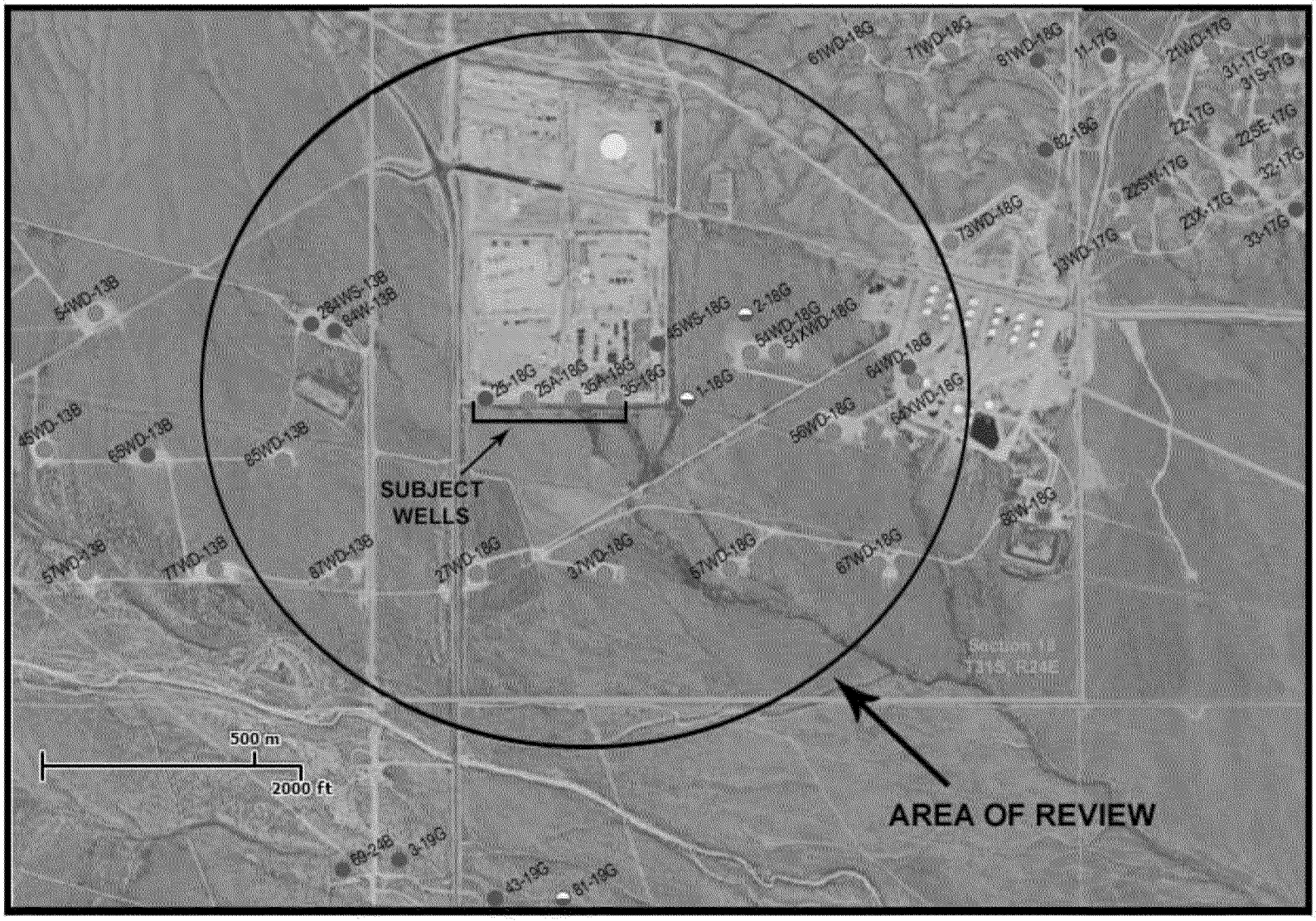
b) *Well 2282WS-14B is on the same geological structure as the permitting wells and the Tulare zone is continuous across the area between well 2282WS-14B and the permitting wells;*

c) *The water sample is current in time having been collected at the end of 2008;*

d) *The TDS of the water sample is 3,500 mg/L, which is in line with the TDS measurements of other Tulare water samples in the area (as reported in* ***EXHIBIT A-1****). For example, the TDS concentration of a Tulare zone water sample, collected from the Elk Hills 33S Produced Water Plant in August 1998, was 4,692 mg/l. This water sample comprised commingled Tulare water sourced from wells in sections 18G, 13B, and 14B); and,*

e) *The results of the salinity calculated from the SP log for well 25-18G (900 to 2,400 ppm) are in good agreement with NaCl salinity reported by the laboratory analysis of the 2282WS-14B Tulare water sample (1,900 mg/L or ppm). The analytical laboratory report is presented in* ***EXHIBIT I-4*** *in the Permit Application. The formation water resistivity was obtained from the readings of the SP log. The salinity calculations are discussed in* ***ATTACHMENT I,*** *Formation Testing Program and the results are presented in* ***EXHIBIT I-5*** *of the Permit Application.*

Wells in Area of Review



California Division of Oil, Gas, and Geothermal Resources, Online Mapping System, December 2011

Structure of the Base Tulare Clay and Locations of Geologic Cross Sections A-A' and B-B'

APPROXIMATE OUTCROP OF BASE TULARE CLAY (MILLIKEN, 1992)

A

46-11B

82W-14B

185

43WS-13B

263.5

284WS-13B

40.7

25-18G

0

35-18G

39

45WS-18G

86W-18G

-358

71-20G

-288

A'

B

B'

88WD-7G

71WD-18G

3-19G

73

T31S/R23E

T31S/R24E

> 787

> 807

> 716

> 750

> 693

> 627

> 646

700

600

500

400

300

200

100

-100

-200

-300

-400

Approximate Limit of Unconfined Tulare Aquifer

Approximate Limit of Confined Tulare Aquifer

well incorporated in cross section line

X, X' endpoints of cross section line

EXPLANATION

- Completed Oil Well
- Plugged and Abandoned Oil Well
- Plugged and Abandoned Dry Hole
- Water Source Well
- Water Disposal Well

Datum = Mean Sea Level

Contour Interval = 100'

1:12000

FEET 0 1000 2000 FEET

All measurements in feet

GEODETIC PARAMETERS

SAN JOAQUIN ENERGY CONSULTANTS, INC.
1400 Easton Drive, Suite 133, Bakersfield, CA 93309

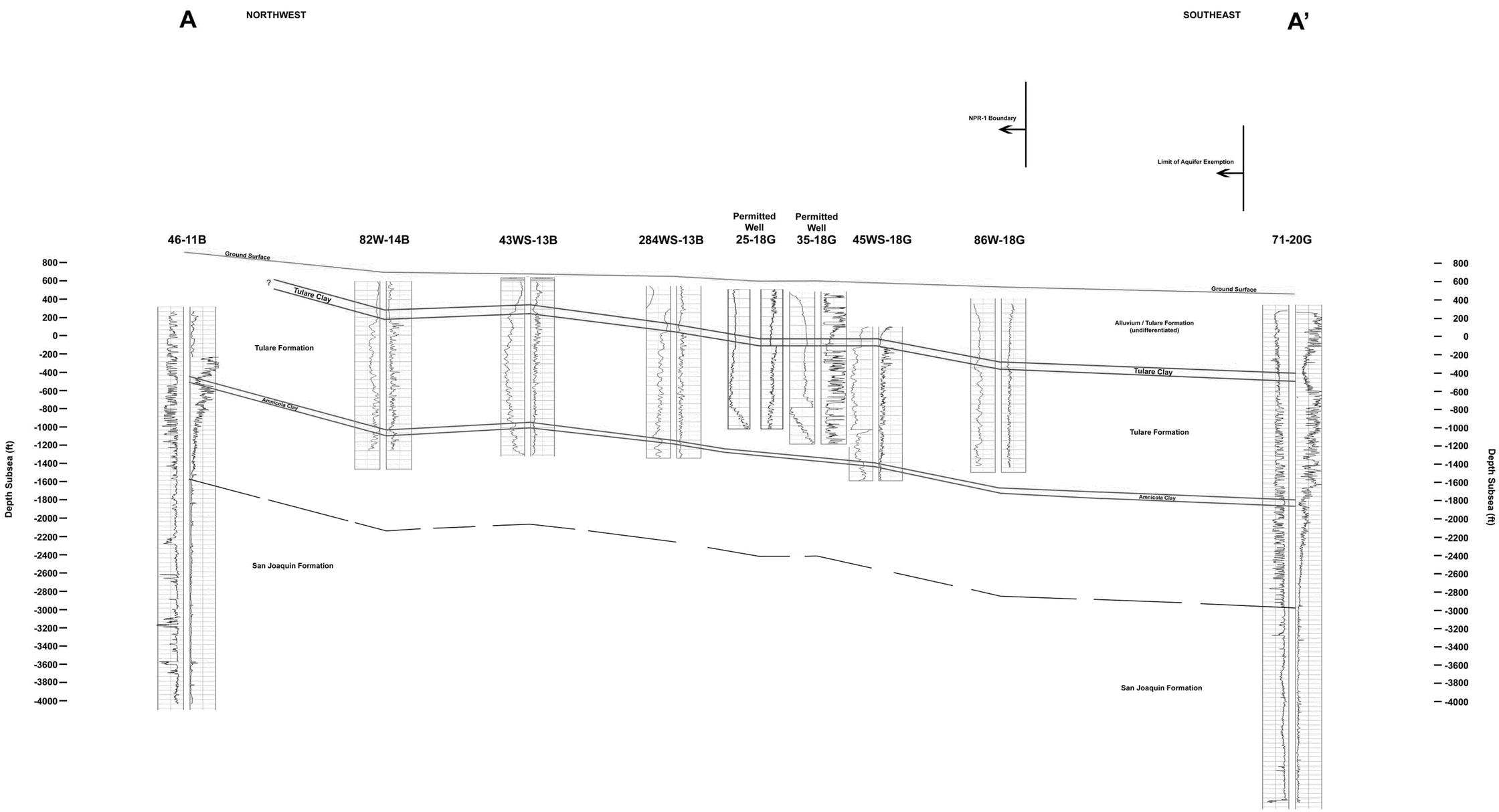
ELK HILLS POWER, LLC

STRUCTURE CONTOUR MAP
BASE TULARE CLAY

CLASS V INJECTION
PERMIT APPLICATION/WDR/ROGER

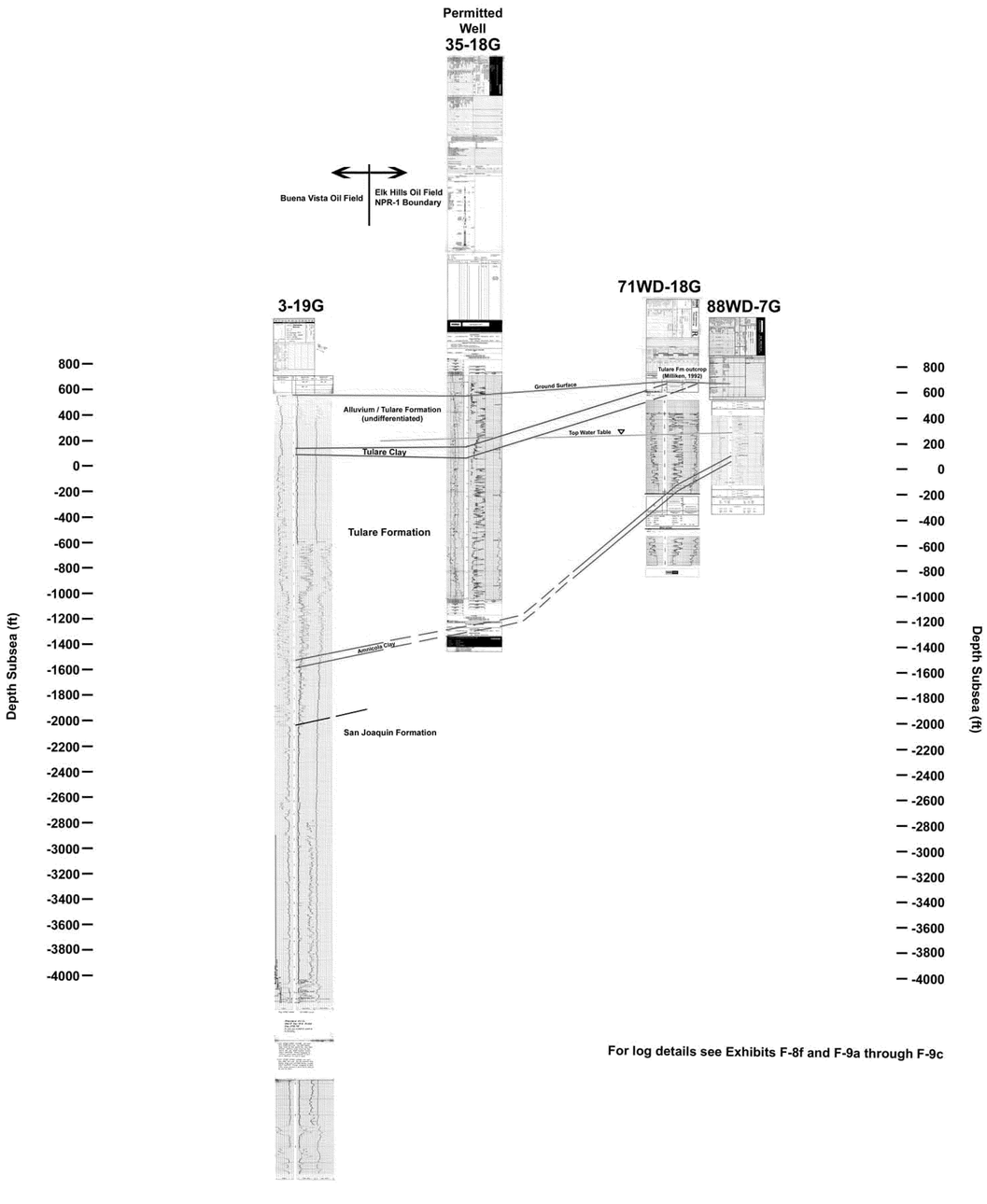
Debra M. Thompson, CA Certified Geologist No. 5347
Date: 4/09 - CA Certified Hydrogeologist No. HG 241

Updated Cross Section A-A'
with Class I Non-Hazardous Injection Wells 25-18G and 35-18G



Updated Cross Section B-B'
with Class I Non-Hazardous Injection Well 35-18G

B SOUTHWEST — NORTHEAST **B'**



For log details see Exhibits F-8f and F-9a through F-9c